



DEPARTMENT OF CONSERVATION

DIVISION OF OIL, GAS, AND GEOTHERMAL RESOURCES

Field: Arroyo Grande Field
County: San Luis Obispo County, California
Class and Well Type: Class II, Water Disposal and Enhanced Oil Recovery
Geologic Formation: Dollie Sands, Pismo Formation

Aquifer Exemption Criteria at Issue:

40 CFR §146.4, Criteria for Exempted Aquifers

- (a) It does not currently serve as a source of drinking water; and
- (b) It cannot now and will not in the future serve as a source of drinking water because:
 - (1) It is mineral, hydrocarbon or geothermal energy producing, or can be demonstrated by a permit applicant as part of a permit application for a Class II or III operation to contain minerals or hydrocarbons that considering their quantity and location are expected to be commercially producible.

California Public Resources Code §3131

- (1) Criteria set forth in Section 146.4 of Title 40 of the Code of Federal Regulations.
- (2) The injection of fluids will not affect the quality of water that is, or may reasonably be, used for any beneficial use.
- (3) The injected fluid will remain in the aquifer or portion of the aquifer that would be exempted.

Synopsis

In 2014, Arroyo Grande oilfield operator Freeport McMoRan requested to expand its existing aquifer exemption area in the Dollie Sands of the Pismo Formation to approximately 1.5 square miles.

The California Department of Conservation, Division of Oil, Gas, and Geothermal Resources (Division), with preliminary concurrence from the State Water Resources Control Board (State Water Board), is proposing to expand the current aquifer exemption designation (area) for the Dollie Sands of the Pismo Formation in the Arroyo Grande oil field (in an unincorporated area of San Luis Obispo County, near the intersection of Ormonde Road and Price Canyon Road).

Subject to approval by the US Environmental Protection Agency (US EPA), the proposed aquifer exemption expansion would allow the State, in compliance with the federal Safe Drinking Water Act, to continue to allow Class II injection into the existing exempted area and into the proposed expanded area (see attached map). Class II activities include enhanced oil recovery injection (steam and water that increases oil production) and the disposal of produced fluids associated with oil and gas production.

The proposed exemption area would be an expansion of the existing aquifer exemption area that was approved in 1983 in conjunction with the US EPA granting the state of California primacy for regulation of Class II injection. In the Arroyo Grande oil field, there are currently two types of injection fluids, steam injection and water disposal of the brine from the reverse osmosis water treatment facility. Both types of injection fluids come from the water produced from the aquifer, which coexists with the oil.

The proposed aquifer exemption area is hydrocarbon (oil) producing, and is capable of commercial oil production. Data supporting that the proposed aquifer exemption is an oil-producing zone include:

- Historic production data in the proposed area;
- Geophysical well logging indicating the presence of hydrocarbons;
- Mud log (detailed subsurface soil and rock descriptions) indicating the presence of hydrocarbons; and
- Lithologic core analysis showing current and residual hydrocarbons in the formation.

Of the sixteen existing water disposal wells in the proposed aquifer exemption area, twelve have successfully produced oil. From those twelve wells, more than 91,000 barrels of oil were

produced from 1977 to 1982. The total oil produced over the productive life of these twelve wells to date is greater than 172,000 barrels. Data from the remaining four water disposal wells indicate the presence of oil within the area proposed for exemption. There are 122 wells currently producing oil within the expanded area proposed for aquifer exemption.

The proposed area underwent a comprehensive survey of water supply wells. The Division and State Water Board have determined that there are no water supply wells located in the existing exempted area and no wells exist in the proposed area of expansion. In addition, none of the nearby water supply wells are pumping water from the Dollie Sands member of the Pismo Formation. The water well survey included reviewing available well completion reports (well logs) from the Department of Water Resources in the proposed area, as well as the surrounding area. The operator also conducted a walking survey of the area and worked closely with staff from both the State Water Board and Central Coast Regional Water Quality Control Board (Central Coast Water Board) in their analysis. Data supporting the proposed aquifer exemption includes a map indicating the location of the nearest water supply wells (see attached map). The absence of water supply wells in the area proposed for aquifer exemption expansion is not a surprise since the Dollie Sands contain significant amounts of oil.

Geologic containment

The Division's District staff compiled an aquifer exemption package using the information provided by the operator and information in the Division's files. The aquifer exemption request was then forwarded to the State Water Board for review by staff, in collaboration with Central Coast Water Board staff. Careful consideration was paid by staff to the information provided that showed injected fluid would remain in the proposed aquifer exemption area and would not be a threat to surface or ground water quality adjacent to the facility.

Staff from the Division and the State Water Board concluded that injected fluid would remain within the proposed aquifer exemption, and would not pose a threat to water of beneficial use outside of the proposed area (Dollie Sands) due to the following conditions present at the site:

- Synclinal structure: The geologic structure within the area of proposed aquifer exemption consists of a downward curving structure known as a syncline. This structure resembles a "bowl," and along with the other containment conditions described below, restricts groundwater movement such that it remains within the syncline and within the area of proposed aquifer exemption. The geologic cross-sections displayed in the

attached map and figures show the synclinal “bowl” feature of the proposed aquifer exemption area (see attached map and cross-sections).

- Stratigraphic and permeability conditions: On the south, east, and west boundaries of the proposed aquifer exemption area there is a facies change (transition from one rock type to another) between sandstone within the proposed aquifer exemption area (which is relatively permeable and allows for movement of fluid) and siltstone and claystone outside the proposed aquifer exemption area (which is significantly less permeable). The transition to a low permeability rock type acts as a fluid barrier in these areas of the proposed aquifer exemption. Additionally, the east and west sides of the proposed exempted area are contained by tar seals. Tar seals act as a fluid barrier and restrict groundwater flow across these boundaries. The proposed exemption area (Dollie Sands) is contained vertically by a combination of tar seals and/or low permeability layers of silt, clay, and cemented sandstone. The geologic cross-sections displayed in the attached figures show the locations of the facies change and tar seals (see attached cross-sections).

Fault barrier: An east-west-trending fault on the north side of the proposed aquifer exemption area acts as a barrier (Arroyo Grande Fault) and restricts groundwater flow across this boundary. The displacement (relative movement) between the two sides of the fault has placed the oil-bearing sandstone inside the proposed aquifer exemption area (that is more permeable) in contact with siltstone and claystone (that is significantly less permeable). This fault traps oil and groundwater on the oil field side of the fault, restricting groundwater/fluid flow across this boundary. The geologic cross-section displayed in the attached figures shows the location of the Arroyo Grande Fault (see attached cross-sections).

Hydraulic containment

- Hydraulic controls: More water is removed from the proposed aquifer exemption area through oil field development (production of oil) than is re-injected as wastewater and steam. Therefore, there is a net loss of water (dewatering) from the proposed aquifer exemption area. As a result, injected Class II fluid within the proposed exempted area is contained hydraulically, both vertically and laterally, due to the inward hydraulic gradient (groundwater flow direction is towards the center of the synclinal geologic structure or “bowl”).

Beneficial Use Well Survey

Based upon information from nearby water well construction, the water supply wells (shown in Figure 1) are not hydraulically connected to the oil bearing zones within the proposed aquifer exemption area due to the geologic and hydraulic containment conditions described above.

Sentry Groundwater Monitoring Wells

As an added measure of caution, sentry groundwater monitoring wells immediately outside the perimeter of the proposed aquifer exemption area will be considered and incorporated into project approvals as needed in order to confirm that injected fluids do not migrate outside the proposed exempted area. The number, spacing, and location of sentry wells will be in a manner that ensures early detection of any change in water quality outside of the proposed aquifer exemption boundary. The information collected from these wells will be made publicly available through the State Water Board's GeoTracker information system.

Further Discussion

The area proposed for exemption has unique geologic features that ensure permitted injection would remain within the proposed area of expansion. The Arroyo Grande oil field is unique in that it is entirely within a "doubly-plunging syncline" (upright bowl shape) and that oil exists throughout the field both laterally and vertically. Tar sands cover the surface to a depth of approximately 250 feet below ground surface. In the case of the Arroyo Grande oil field, over millennia, oil has been slowly seeping from the syncline to the surface of the earth. Oil has weathered (dried) and created thick tar sand at the surface.

The north boundary for the proposed exemption area expansion is the Arroyo Grande fault. Over a long period of time, this inactive fault has moved the layers of rock underground so they no longer lay even with each other. The lithologic offset creates a barrier in which restricts fluid migration from one side of the fault to the other. The aquifer is contained on the other three sides through a combination of different mechanisms.

The syncline structure of the aquifer cannot "fill up" or overflow with the injection water because as oil is removed from the proposed area, large amounts of water are produced. On average, 95% of the fluid pumped from the Arroyo Grande oil field is produced water. Water must be separated before oil is refined (processed). The produced water is then sent through water softening treatment process to remove the mineral hardness. Approximately 20,000 barrels a day (or 840,000 gallons) of softened water is then sent to a reverse osmosis plant where it is treated (under permit from the Central Coast Water Board) and is placed into Pismo Creek which flows outside the oil field boundary and helps to support fish habitat and recharge

groundwater, leaving a net loss of fluid in the proposed area. The remainder of the softened water is turned into steam and injected into the oil-bearing zone to increase flow to the production wells. By removing water from the syncline structure and strictly monitoring fluid flow, the “bowl” will not overflow into neighboring aquifers.

The second layer of protection for nearby aquifers is that the bowl is surrounded to the east, south, and west with a layer of nearly impermeable siltstone and claystone called the Miguelito member of the Pismo Formation. The syncline bowl of the Arroyo Grande oil field is filled with the permeable Dollie Sands that allows fluid to flow. Dollie Sands permeability values range from 300 millidarcys to 2,000 millidarcys. The larger the millidarcy value indicates that it is easier for fluid to flow. The base of the syncline bowl and surrounding the Dollie Sands is the Miguelito siltstone and claystone that has a permeability value of 1.7 millidarcys, which is 400 times less permeable than the Dollie Sands. This low permeability provides an additional barrier that prevents fluid from flowing out of the Dollie Sands into adjoining lithologic formations.

Conclusion

Data related to the proposed expanded area to be exempted indicate that:

- 1) The proposed aquifer is not currently being used for any beneficial use;
- 2) The proposed aquifer to be exempt is currently hydrocarbon producing or capable of production in commercial quantities;
- 3) The injection of fluids will not affect the quality of water that is, or may reasonably be, used for any beneficial use; and
- 4) The injected fluid will remain in the portion of the aquifer that would be exempted.

Based on these factors, in addition to the previously described site conditions, the State of California is preliminarily proposing an expansion of the existing aquifer exemption in the Dollie Sands located within the Arroyo Grande field.